Application of the dinuclear system model to the description of half-lives of heavy and superheavy nuclei

Ivan Rogov

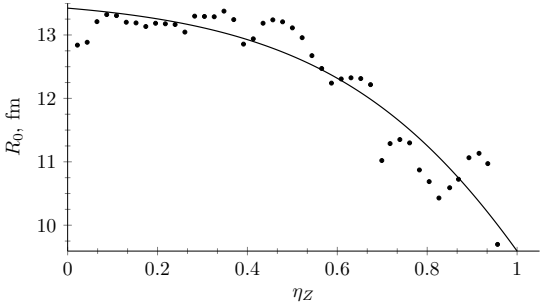
BLTP, JINR

14th ITP/CAS–BLTP/JINR Joint Workshop

Nanjing, 2026

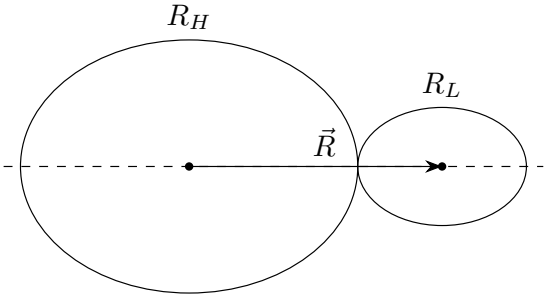
Dinuclear system (DNS)

DNS preformation (η_Z)



Spectroscopic factor S_L

DNS decay (R)



Penetration probability P_L

$$\eta_Z = \frac{Z_H - Z_L}{Z_H + Z_L}$$

DNS state

The system is described by stationary wave function $\Psi(\eta_Z)$:

$$\hat{H}\Psi_n(\eta_Z) = E_n\Psi_n(\eta_Z),$$

where

$$\hat{H} = \hat{T}_{\eta_Z} + U(\eta_Z)$$

Kinetic energy

$$\hat{T}_{\eta_Z} = \frac{\hbar^2}{2}\frac{\partial}{\partial\eta_Z}B^{-1}_{\eta_Z}\frac{\partial}{\partial\eta_Z}$$

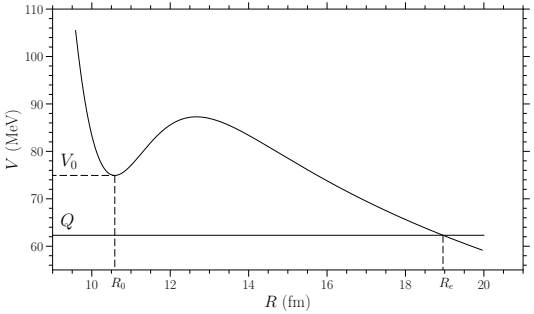
Potential energy

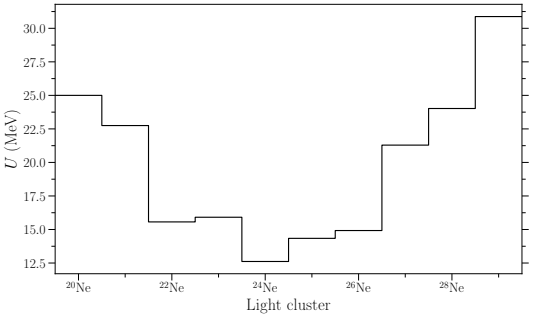
[G. Adamian *et al.* Int. J. Mod. Phys. A, 1996]

$$U(R,\eta_Z) = V(R,\eta_Z) - (Q_M - Q_L - Q_H)$$

$$V(R,\eta_Z) = V_{\mathrm{C}}(R,\eta_Z) + V_N(R,\eta_Z) + V_r(R,\eta_Z)$$

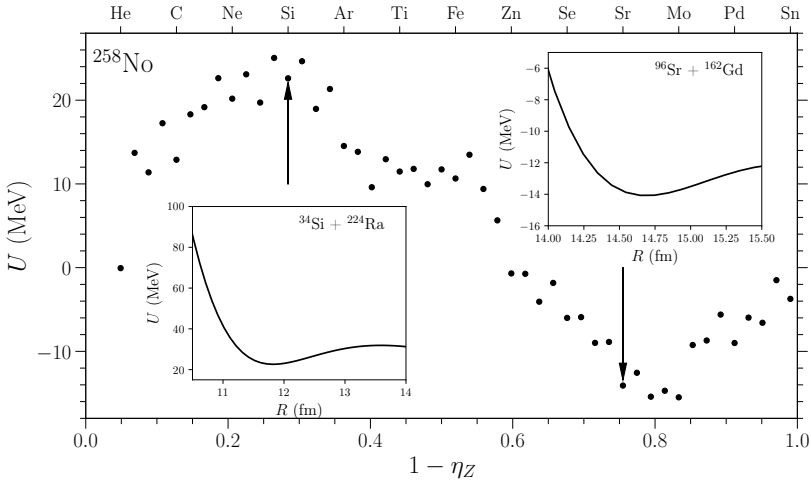
Driving potential



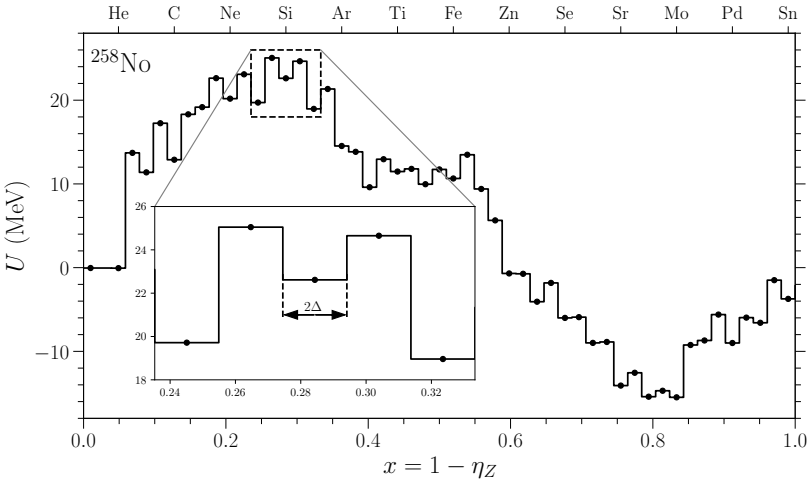


$$a_0 = 0.47 - 0.56 \text{ fm}; \quad r_0 = 1.00 - 1.16 \text{ fm}$$

Formation of the driving potential

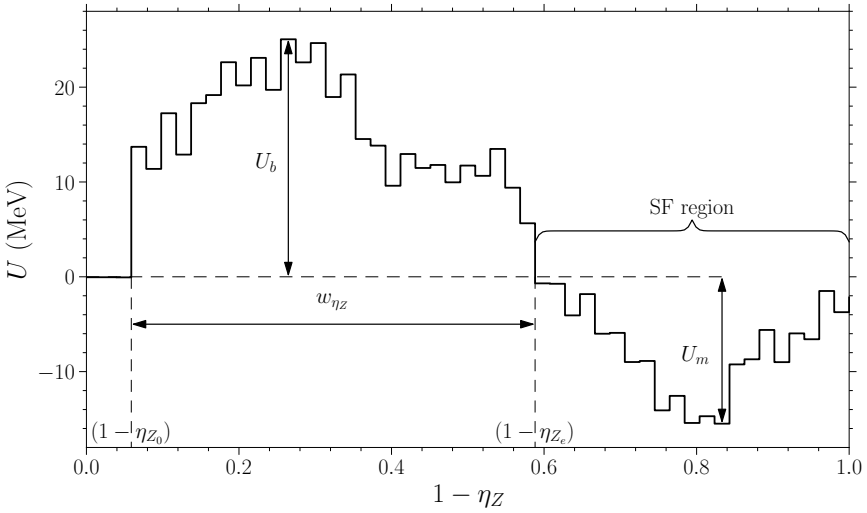


Formation of the driving potential



$$\eta_Z \to x = 1 - \eta_Z; \quad \Delta = 1/Z;$$

Driving potential characteristics



Half-lives

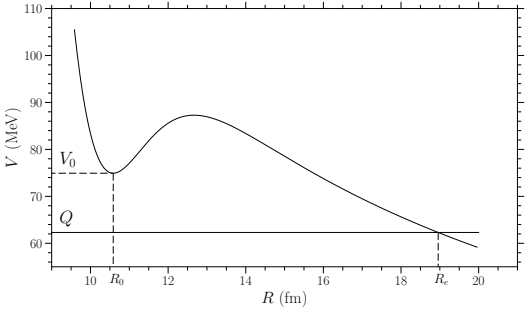
$$S_L = \int_{\eta_Z(Z_l)-\Delta}^{\eta_Z(Z_L)+\Delta} |\Psi(\eta_Z)|^2 d\eta_Z$$

$$\Delta = 1/Z$$

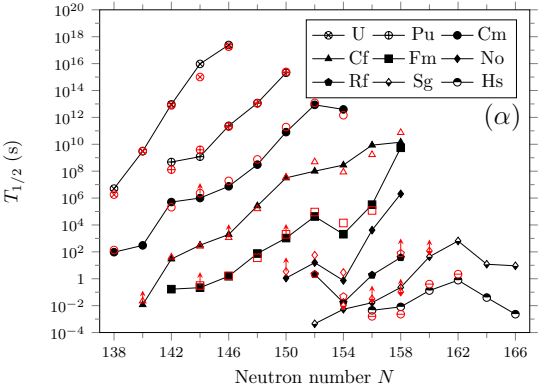
$$\Gamma_L = \frac{\hbar\omega_0}{\pi} S_L P_L,\ T_{1/2} = \frac{\hbar \ln 2}{\Gamma_L}$$

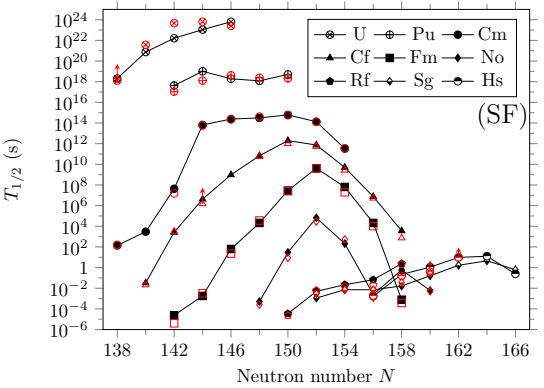
$$T_{1/2} = \frac{\pi \ln 2}{\omega_0 S_L P_L}$$

$$P_L = \left(1 + \exp\left[\frac{2}{\hbar} \int_{R_0}^{R_{J1}} \sqrt{2\mu(V(R,\eta_Z) - Q)} dR \right] \right)^{-1}$$

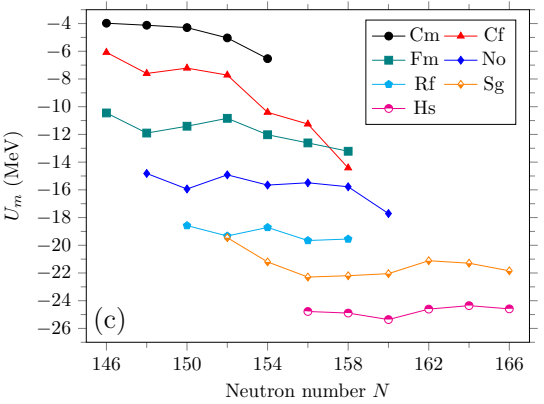


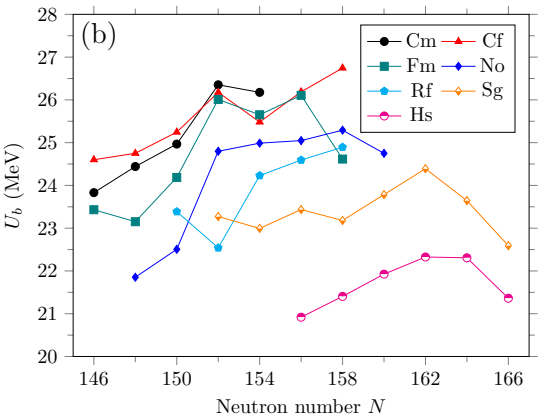
Even-even nuclei half-lives



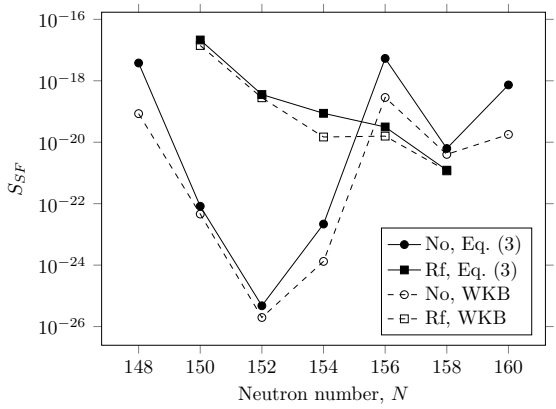


Driving potential characteristics



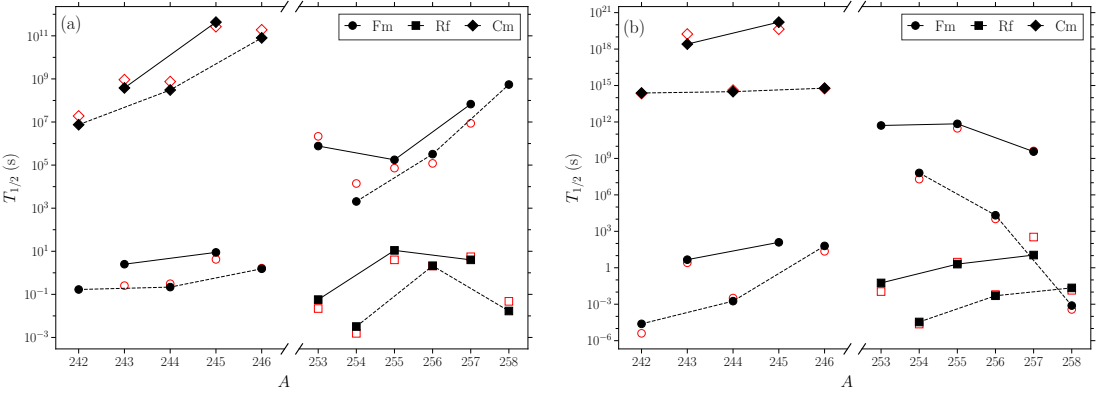


WKB-approximation

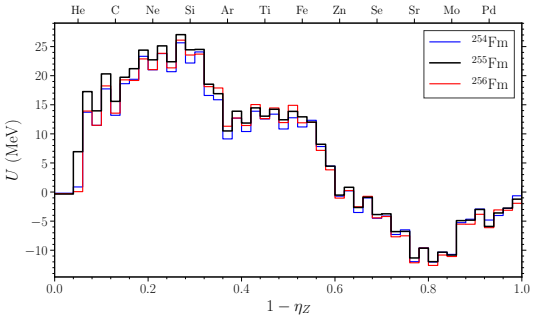


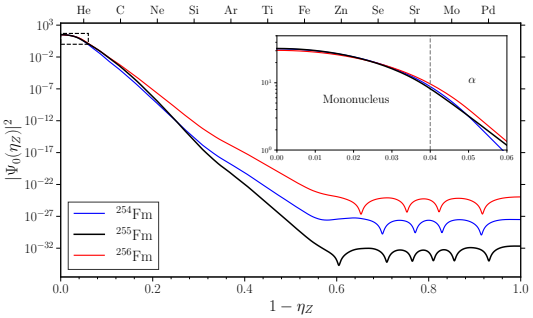
$$S_{SF} = \left(1 + \exp\left[\frac{2}{\hbar}\int\limits_{\eta_{Z0}}^{\eta_Z} \sqrt{2U(R,\eta_Z,\Omega)/\left(B^{-1}\right)_{\eta_Z}} d\eta_Z\right]\right)^{-1}$$

Even-odd nuclei half-lives



Driving potential influence

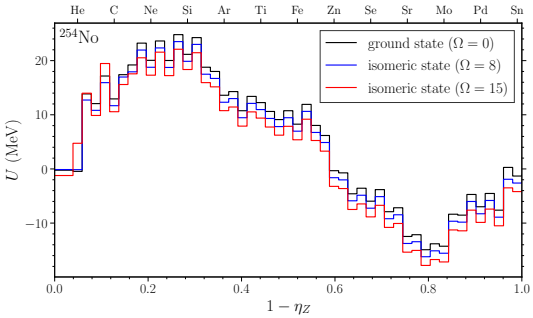


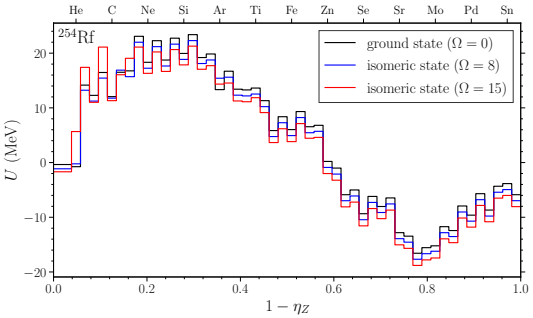


Rotational part influence

	Ω	S_α	S^*_α	$T_{1/2}$, s	$T^*_{1/2}$, s	$T^{\text{est}}_{1/2}$, s
^{243}Cm	5/2	0.0526	0.0707	2.57×10^{18}	1.02×10^{14}	2.75×10^{14}
^{245}Cm	7/2	0.0428	0.0947	1.65×10^{20}	7.34×10^{14}	4.35×10^{14}
^{243}Fm	7/2	0.0712	0.0904	3.51	3.14×10^{-4}	2.08×10^{-4}
^{255}Fm	7/2	0.0527	0.0816	3.01×10^{11}	1.62×10^{6}	1.16×10^{6}
^{257}Fm	9/2	0.0481	0.0888	4.13×10^{9}	1.19	4.02
^{253}Rf	7/2	0.0888	0.0947	5.64×10^{-2}	2.21×10^{-5}	–
^{255}Rf	9/2	0.0691	0.0930	2.00	2.95×10^{-3}	4.14×10^{-4}
^{257}Rf	1/2	0.0893	0.0918	1.11×10^{1}	3.99×10^{-2}	1.05×10^{-2}

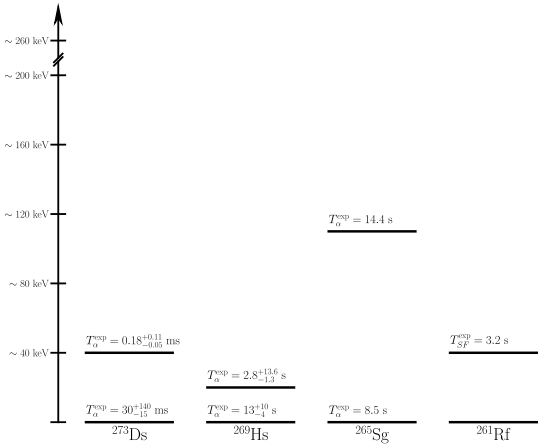
Isomers decay





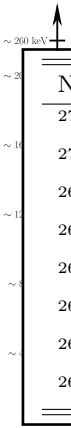
Decay chains ^{273,275}Ds

[Yu. Ts. Oganessian, V. K. Utyonkov *et al.* Phys. Rev C 109, 054307 (2024)]



Decay chains ^{273,275}Ds

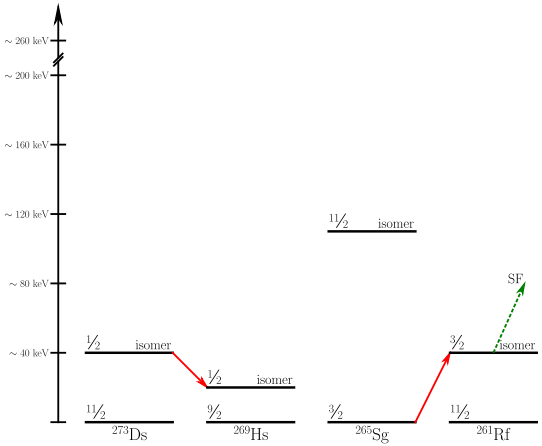
[Yu. Ts. Oganessian, V. K. Utyonkov *et al.* Phys. Rev C 109, 054307 (2024)]



Nucleus	Decay mode	$T_{1/2}^{\mathrm{exp}}$	E_α (MeV)	Q_α (MeV)	Spin	T_α^{calc}	$T_{\mathrm{SF}}^{\mathrm{calc}}$
^{273}Ds	α	30^{+140}_{-15} ms	10.93(2)	11.09(2)	11/2	87 ms	110 s
^{273}Ds	α	$0.18^{+0.11}_{-0.05}$ ms	11.10(7)	11.27(7)	1/2	0.21 ms	47 s
^{269}Hs	α	13^{+10}_{-4} s	9.20(4)	9.34(4)	9/2	15 s	2.2 h
^{269}Hs	α	$2.8^{+13.6}_{-1.3}$ s	9.08(15)	9.22(15)	1/2	3 s	14 min
^{265}Sg	α	$8.5^{+2.6}_{-1.6}$ s	8.84(5)	8.97(5)	11/2	11 s	14 h
^{265}Sg	α	$14.4^{+3.7}_{-2.5}$ s	8.69(5)	8.82(5)	3/2	12 s	59 min
^{261}Rf	α	68 ± 3 s	8.28(2)	8.41(2)	11/2	87 s	12 min
^{261}Rf	SF	$2.6^{+0.7}_{-0.5}$ s	8.51(6)	8.64(6)	3/2	7.4 s	3.7 s

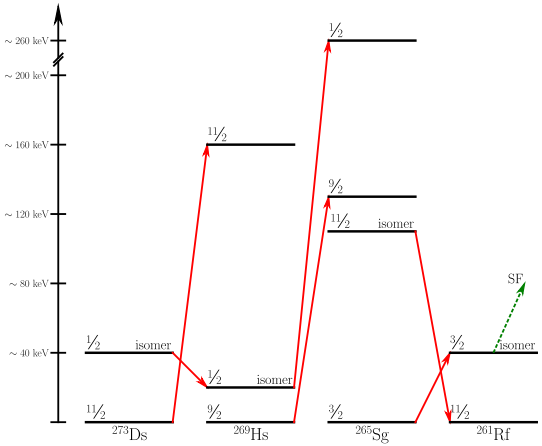
Decay chains ^{273,275}Ds

[Yu. Ts. Oganessian, V. K. Utyonkov *et al.* Phys. Rev C 109, 054307 (2024)]



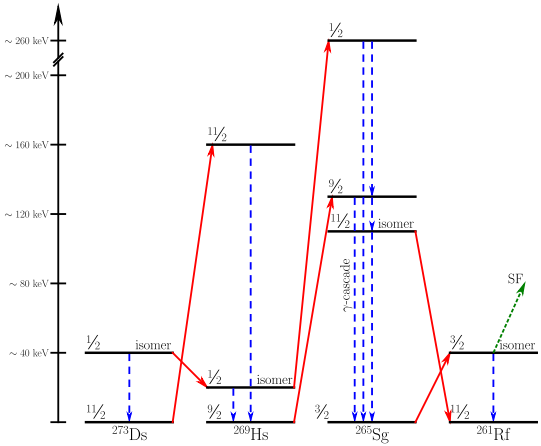
Decay chains ^{273,275}Ds

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Decay chains ^{273,275}Ds

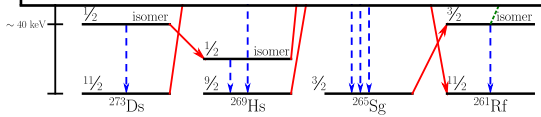
[Yu. Ts. Oganessian, V. K. Utyonkov *et al.* Phys. Rev C 109, 054307 (2024)]



Decay chains ^{273,275}Ds

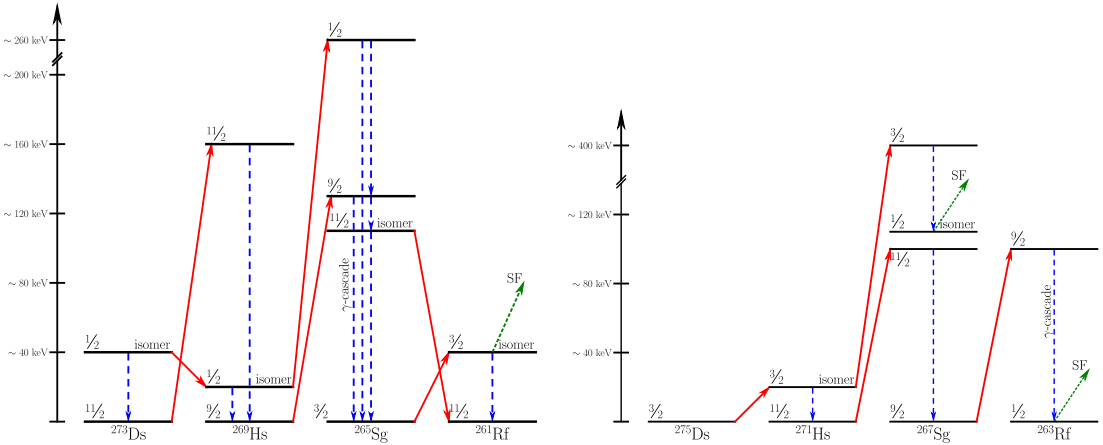
[Yu. Ts. Oganessian, V. K. Utyonkov *et al.* Phys. Rev C 109, 054307 (2024)]

Nucleus	Decay mode	$T_{1/2}^{\text{exp}}$	E_α (MeV)	Q_α (MeV)	Spin	T_α^{calc}	$T_{\text{SF}}^{\text{calc}}$
^{275}Ds	α	$0.43^{+0.29}_{-0.12}$ ms	11.20(2)	11.37(2)	3/2	0.22 ms	2.0 s
^{271}Hs	α	$7.1^{+8.4}_{-2.5}$ s	9.05(2)	9.18(2)	3/2	5.1 s	6.0 min
^{271}Hs	α	46^{+56}_{-16} s	9.34(2)	9.48(2)	11/2	63 s	21 h
^{267}Sg	SF	100^{+92}_{-39} s			1/2	16 h	140 s
^{267}Sg	α	$9.8^{+11.3}_{-4.5}$ min	8.27(2)	8.40(2)	9/2	6 min	2.9 h
^{263}Rf	SF	$5.1^{+4.6}_{-1.7}$ s			1/2	0.5 h	6.4 s

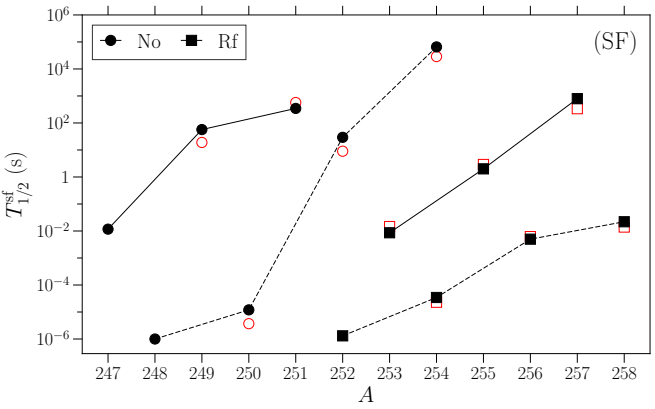


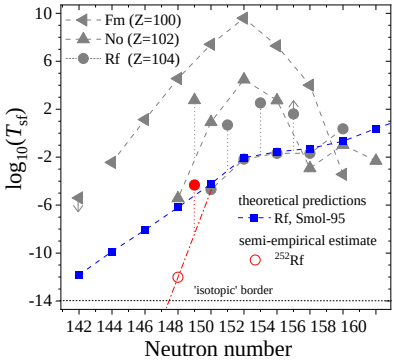
Decay chains ^{273,275}Ds

[Yu. Ts. Oganessian, V. K. Utyonkov *et al.* Phys. Rev C 109, 054307 (2024)]



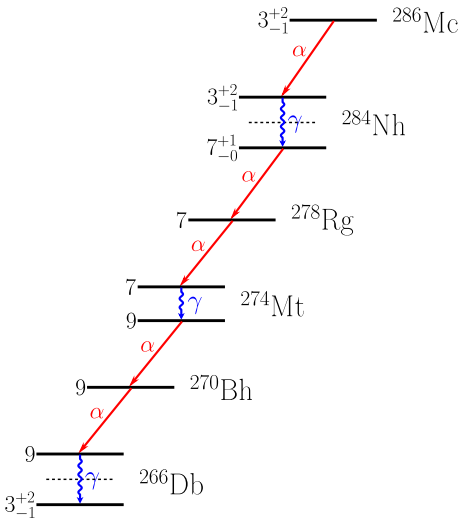
Proton-rich nuclei



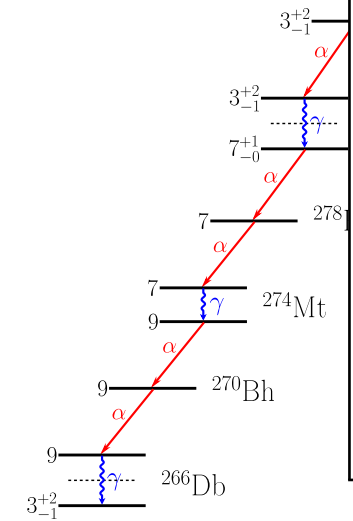


[Khuyagbaatar et al., Phys. Rev. C 104, L031303 (2021)]

^{286}Mc decay chain

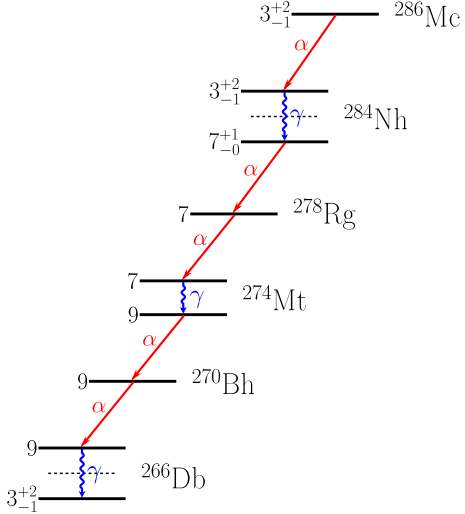


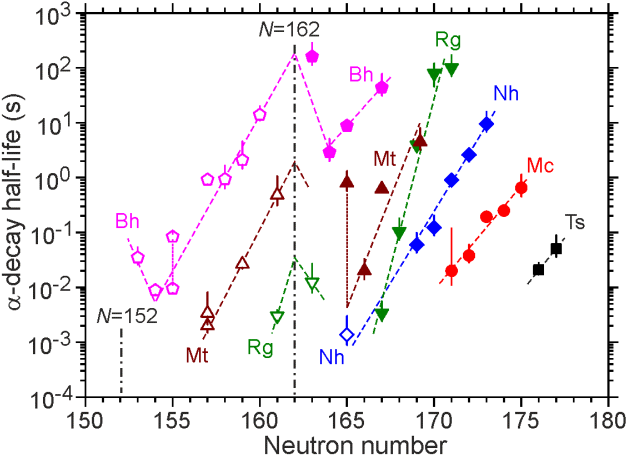
^{286}Mc decay chain



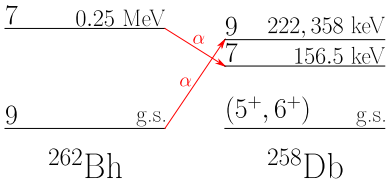
Nucleus	Q_M (MeV)	T_α^{exp} (s)	K	T_α^{th} (s)	$T_{\mathrm{SF}}^{\mathrm{th}}$ (s)
^{286}Mc	174.59	$2^{+9.8}_{-0.9} \times 10^{-2}$	5	1.12×10^{-1}	2.90×10^{5}
			3	2.46×10^{-2}	1.98×10^{5}
			2	1.04×10^{-2}	1.60×10^{5}
^{282}Nh	161.31	$6^{+3.9}_{-1.7} \times 10^{-2}$	8	1.81×10^{-1}	5.28×10^{1}
			7	5.30×10^{-2}	2.02×10^{1}
^{278}Rg	148.13	$3.4^{+2.2}_{-1} \times 10^{-3}$	7	3.67×10^{-3}	4.63×10^{2}
^{274}Mt	134.83	$0.8^{+0.52}_{-0.23}$	9	0.896	6.78×10^{5}
^{270}Bh	122.35	$2.62^{+1.2}_{-0.48} \times 10^{2}$	9	2.41×10^{2}	2.22×10^{6}
^{266}Db			5	2.99×10^{5}	5.72×10^{2}
			3	4.47×10^{4}	1.04×10^{2}

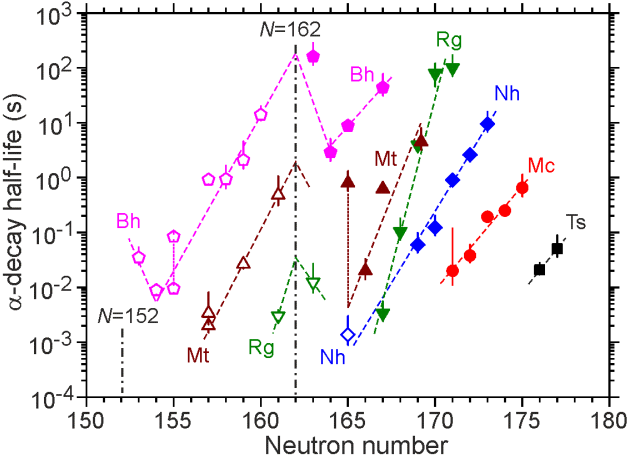
^{286}Mc decay chain





^{286}Mc decay chain





Thank you for your attention